# Moon or Mars: What Is the Next Logical Step for NASA?

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Abstract

This thesis examines the United States Space Program from its inception in 1958 with the formation of NASA, its rich history of space exploration, and its current status under the space policy of President Barack Obama's administration. With the cancellation of Constellation's human spaceflight program in 2010, the termination of the Space Shuttle in 2011, and the future expiration of the International Space Station in 2024, the morale at NASA is at an all-time low. NASA has become steeped in bureaucracy and is the victim of political chess games.

My research included the perusal of relevant articles from the historical literature and current periodicals, reviews of current Congressional hearings, personal interviews with high-ranking aerospace insiders and government officials, and an internship at NASA Headquarters in Washington, D.C. The information gathered from these sources has been categorized into six evaluative categories and then synthesized into this document with the hope of a fair assessment of the strategy and direction of one of the most respected institutions in the world.

What is the next step for NASA? Is it returning to the Moon, or is it a journey to Mars? With shrinking space budgets, the lack of political will, and shortages of technological and medical knowledge, the compass points to NASA's next logical step of possibly going back to the Moon. NASA is at a critical juncture. The decisions made by the next president and Congress will determine the future of human exploration in our solar system and vast universe for decades to come.

## Dedication

The NASA brand is recognized worldwide and carries with it the awe-inspiring achievements of the dedicated men and women of the United States of America who have worked for NASA and accomplished what many thought to be impossible. A few of you have received recognition, but the majority of you have not. Therefore, to all of you, both past and present I dedicate this work. As it has been said, NASA turns science fiction into science fact.

Through all of NASA's ups and downs, the vision and passion to explore our solar system and beyond still burns brightly in the hearts and minds of its people. You have inspired all of us to reach for our dreams, never give up, and to recognize that "Failure is not an option." For this, we all thank you.

# Acknowledgements

I would like to thank my incredible mother and father, my eleven beautiful children, and my steadfast friends; the inspiring deans, advisors, and faculty at the University of Oklahoma and Harvard University, and my loving God. During the difficult times, each of you whispered in my ear "You can do it!" For this I will always be grateful. It is to all of you I dedicate this work, as well as the many opportunities my education has afforded me. I promise to make this world a better place!

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# Chapter I

## Introduction

Consensus is building worldwide for returning humans to the surface of the Moon. China, Russia, India, and the European Space Agency are setting their sights on our closest neighbor in outer space. From the beginning of time, the Moon has helped define our life here on Earth, as this celestial body is critically connected to us in a variety of ways. The Moon offers us enormous value scientifically, as well as the possibility of rich, raw resources that can benefit our life on planet Earth.

This thesis will investigate the rationale for NASA to not only return to the lunar surface, but to lead the way with its international partners. Although the horizon goal is Mars, the lack of political will, shrinking space budgets, and the lack of technological and medical knowledge points the compass in the direction of possibly going back to the Moon. I argue that the Moon must serve as a proving ground for a crewed mission to Mars because of the life-threatening hazards of living and working in deep space. Personally, I want nothing more than NASA to advance toward ambitious human exploration. But, it must be done in an orderly and safe manner to preserve this inspiring American ideal.

## Chapter II

## Research Problem

On July 20, 1969, astronaut Neil Armstrong stepped on the Moon, and with that step he accomplished one of the greatest achievements in the history of humankind. Subsequent missions to explore the lunar surface continued, with astronaut Eugene (Gene) Cernan leaving the last footprint on the Moon in December 1972.[1] Since that time, there have been several shuttle missions, and an extensive human presence in space on the International Space Station (ISS). These are significant accomplishments and have created positive results for humankind. But for the past 40 years Earthlings have been trapped in the repetitive cycle of low Earth orbit (LEO). If we are to explore this solar system and universe in which we reside, we must exit from this pattern, escape the gravity well of Earth, and once again reach for the stars.

Human exploration has inspired mankind since the beginning of civilization. Exploration is one of the characteristics of a progressing society. When a nation explores into the unknown, it leads to innovation, discovery and, ultimately, prosperity. In addition, it fosters national prestige and inspires its citizens, both old and young, to pursue excellence. What is the next logical step for NASA? Is it to return to the Moon or Mars?

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[1] Andrew Chaikin, *A Man on the Moon* (New York: Penguin Books, 1994).

This thesis addresses the following questions:

- What are the advantages and disadvantages of a mission to the Moon?
- What are the advantages and disadvantages of a mission to Mars?

I evaluated these questions through an analysis of the following six categories: physiological, psychological, technological, economical, international, and national. I chose these categories because they are possibly the most critical for making a suitable decision. Arguably, other important categories exist, but a consideration of these critical categories rendered what I believe is a qualified recommendation.

Within the categories of physiological and psychological, I explored the advantages and disadvantages of both missions in terms of the effects of spending long periods of time in space as it relates to the human body as well as the mental and emotional consequences. In the technical category, I studied the advantages and disadvantages of both mission and their material feasibility. For example, technology and natural resources need to be acquired and deployed. In economical, I explored the advantages and disadvantages of both missions in terms of current budgetary consideration, the overall fiscal health of our citizens, and the financial implications of such manned missions. In international, I explored the advantages and disadvantages of both missions in terms of world political and social consensus building. These missions could build a strong shared identity across nations. This collaboration could lead to a group of nations working together interdependently, which could buttress peaceful international relations. In national, I looked at the advantages and disadvantages of both missions in relation to its implications for U.S. citizens and the U.S. government. The comparison of the advantages and disadvantages of each mission across these six evaluative categories revealed which mission is the next logical step for NASA.

This analysis matters at this point in time because the U.S. and the world are at an important crossroads. Continuing to invest in human space exploration yields tangible, and more importantly, intangible rewards. In particular, human space exploration holds the promise of generating a return on investment in terms of technology and new knowledge creation which, in turn, can provide solutions to unanswered problems that humans face on a daily basis on Earth: disease, climate change, clean energy, and unemployment. Perhaps more importantly, continued investment in human space exploration generates priceless symbolism and inspiration from which nations can make meaning and possibly develop a more united identity and purpose which, arguably, could reduce their tendency to compete through acts of war and violence.

> I was nine years old during Apollo 11, when Neil Armstrong and Buzz Aldrin stepped on the Moon, and it influenced me to be an engineer. It stopped the world! I have given NASA tours to my friends, and then their children went on to become engineers. Space inspires the lives of people, and we need to communicate everything we accomplish, because creating this awareness pays large dividends in adults, as well as our children.[2]

[2] Kathy Laurini, 30-year veteran of the NASA Human Exploration Program. Personal interview, International Space University, July 28, 2015.

Chapter III

Definition of Terms[3]

*Apollo*: A program of space flights undertaken by the U.S. to land a man on the Moon. The first lunar landing was achieved by the Apollo Program on July 20, 1969.

*Ares I*: The rocket developed by NASA under the Constellation Program that would launch astronauts in the Orion spacecraft.

*Ares V*: The rocket developed by NASA under the Constellation Program that would launch cargo intended for destinations beyond low Earth orbit.

*Asteroid*: Any numerous small celestial bodies composed of rock and metal that move around the sun.

*Astronaut*: A person trained to travel in a spacecraft.

*Cosmonaut*: A Russian astronaut.

*Central Intelligence Agency (CIA)*: An independent agency of the United States government responsible for collecting and coordinating intelligence and counterintelligence activities abroad in the national interest.

*Cislunar*: The space between the Earth and the orbit of the Moon.

*Cold War*: The tense relationship between the United States and the Soviet Union from 1945 to approximately 1991. There was an extreme buildup of weapons of mass destruction, but neither side ever went to war, as the consequences would have been apocalyptic.

[3] Merriam-Webster.com

*Columbia*: NASA's first Space Shuttle, which completed 27 missions from 1981 to 2003. Nearing the end of its 28th mission, it disintegrated during re-entry, causing the death of all seven astronauts on board.

*Constellation Program*: A human space exploration program, created by NASA under the leadership of President George W. Bush, from 2005 to 2009.

*Corona Program:* Operated by the CIA to produce strategic reconnaissance satellites that could obtain intelligence on the Soviet Union.

*Critical Question*: The "critical question" is the foundation of this thesis: What is the next logical step for NASA? Is it a Moon or a Mars mission? Anytime the phrase "critical question" is used, it refers to this strategic question.

*Extravehicular Activity (EVA)*: Activity performed outside a spacecraft by an astronaut or cosmonaut in space.

*Entry, Descent, and Landing (EDL)*: The components, systems, qualifications, and operations to safely and usefully bring a vehicle from approach conditions to contact with the surface of a solar system body. In addition to landing from space on the surface, EDL includes the mission that exits the body.

*Gemini*: NASA's second human spaceflight program between project Mercury and Apollo. Ten two-man crews flew low Earth orbit missions between 1965 and 1966.

*Hubble Space Telescope (HST)*: A space telescope launched into low Earth orbit in 1990 to allow a deep view into outer space.

*In Situ Resource Utilization (ISRU)*: The practice of leveraging resources found or manufactured on celestial bodies to fulfill the requirements of a space mission. ISRU enables long-term human missions by minimizing the amount of materials transported from Earth.

*International Space Station (ISS)*: An inhabited artificial satellite launched in 1998. It is modular in design and serves as a research laboratory. It is an example of successful international collaboration.

*International Space Exploration Coordination Group (ISECG)*: A voluntary, non-binding organization established in 2007 to advance the global exploration strategy by providing a forum where interested agencies can share their objectives and plans, and make use of their synergies. Currently, ISECG consists of 14 space agencies.

*Kennedy Space Center (KSC)*: A launch facility operated by NASA, named in honor of President John F. Kennedy who proposed the Apollo Program.

*Lunar Surface Systems (LSS)*: Created by NASA in 2007 to provide the lunar architecture in the areas of exploration, science and commerce needed to promote a sustainable human presence on the Moon. LSS would also serve as a stepping stone for future exploration of Mars and Earth's solar system.

*Low Earth Orbit (LEO)*: An orbit around Earth at an altitude between 160 and 2000 kilometers (99 to 1,200 miles). Apollo was the only program to take astronauts beyond low Earth orbit. The International Space Station and the majority of satellites are in the vicinity of LEO.

*Mars vs. Moon Mission*: The central question under investigation for this thesis: comparing the relative merits of sending manned spacecraft to Mars or to the Moon as a starting point for human colonization of space.

*Mir*: A space station owned by the Soviet Union that operated in low Earth orbit from 1986–2001.

*National Academy of Sciences (NAS)*: A government-mandated committee created in 1863 by President Abraham Lincoln to conduct studies requested by the federal government in the area of science, engineering, and medicine.

*National Aeronautical and Space Administration (NASA)*: The United States government agency responsible for the civilian space program as well as aeronautics and aerospace research.

*National Reconnaissance Office (NRO):* Established in 1961 by President Dwight D. Eisenhower, the NRO was committed to utilizing outer space for potential military uses.

*Orion*: A spacecraft being developed by NASA and intended to carry a four-man crew beyond low Earth orbit into outer space.

*Project Mercury*: NASA's first human spaceflight program, which put a one-man crew into low Earth orbit. The Mercury program operated from 1959 to 1963, successfully completing six manned missions. Mercury was the precursor to the Gemini and Apollo programs.

*STEM*: Referring to the academic disciplines of science, technology, engineering, and mathematics.

*Skylab*: NASA's first space station, operating from 1973–979.

*Soyuz*: A Russian spacecraft ferrying cosmonauts and astronauts to and from the International Space Station.

*Spacelab*: A research laboratory housed in the cargo bay of the Space Shuttle, in operation from 1973–1979.

*Space Race*: The competition between nations regarding achievements in the field of space exploration. Used in this thesis, it defines the competition between the United States and the Soviet Union between 1957 and 1969.

*Space Shuttle/Space Transportation System (STS)*: NASA’s partially reusable space system designed to launch satellites, the Hubble Space Telescope, and components of the International Space Station. The Space Shuttle operated from 1981 to 2011 and flew 135 missions. Both Challenger and Columbia space shuttles were destroyed during their missions and the 14 crew members in both shuttles perished.

*SpaceX*: A private U.S. aerospace manufacturer founded in 2002 by Elon Musk. The company is headquartered in Hawthorne, California. SpaceX designed the Dragon spacecraft, which is launched by a Falcon 9 rocket. It is the first privately held company to send an unmanned spacecraft to the International Space Station.

*Sputnik 1*: The first artificial Earth satellite, which was launched by the Soviet Union on October 4, 1957.

*Suborbital*: A spaceflight in which a spacecraft reaches space, but its trajectory intersects the atmosphere of the gravitational body from which it was launched so it does not complete one orbital revolution.

*United Nations Office of Outer Space Affairs (UNOOSA)*: An organization that works to promote international cooperation in the peaceful use and exploration of space, and in the utilization of space science and technology for sustainable economic and social development.

*Yuri Gagarin*:  A Russian cosmonaut who was the first human to journey into space.

# Chapter IV

## Historical Background

After the conclusion of World War II in 1945, a new ideological battle (termed the Cold War) began to emerge between the world's two superpowers—the communist Soviet Union and the democratic United States. Each country attempted to show superiority, both militarily and technologically, hoping to prove that its communist or capitalist system, respectively, was best. As the rivals contended for superiority, outer space became a spectacular arena for their competition.[4]

### Sputnik

On October 4, 1957, the Soviet Union struck a defining blow with its launch into space of Sputnik 1, the first artificial satellite.[5] This satellite launch not only inaugurated the Space Age, but also the space race fueled by Cold War tensions between the United States and the Soviet Union. This technological achievement surprised Americans, proving that the Soviets were, at that time, more advanced technologically, and hinted at an underlying, misinformed arrogance held by the U.S. that created such a surprise.

Almost four months later on January 31, 1958, the U.S. launched its first satellite, Explorer. Thereafter, the Soviets began to achieve a series of ideological and

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[4] John F. Kennedy Presidential Library and Museum, "The Cold War." http://www.jfklibrary.org/JFK/JFK-in-history/The-Cold-War.aspx.

[5] Steve Garber, "Sputnik and the Dawn of the Space Age." http://history.nasa.gov/sputnik/2007.

technologically charged “firsts” during the years 1958 to early 1961. These firsts included launching a dog into orbit on Sputnik II, as well as the first man to journey into outer space—Yuri Gagarin, on April 12, 1961. Additional achievements included the first woman in space, the first spacewalk, the first human to orbit the Moon, and the first unmanned spacecraft to land on the lunar surface.[6] Propelled by these Soviet achievements, the U.S. government, and the military, science, and technological communities united their efforts to move forward quickly in the space race, as they feared the Soviets might be considering more belligerent plans involving the creation and use of this new technology in space.

## The Creation of NASA

The U.S. was both fearful and embarrassed, as the nation prided itself on being superior both militarily and technologically. This sense of national pride supplied President Dwight D. Eisenhower with sufficient political will to create the National Aeronautics and Space Administration (NASA) on July 29, 1958.[7] Although this organization was designated as a civilian entity with the purpose of peaceful pursuit of outer space, Eisenhower created two additional national security space organizations that would operate in conjunction with NASA. First was the Corona program, operated by the CIA, which produced strategic reconnaissance satellites to obtain intelligence on the

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[6] Elizabeth Hanes, “From Sputnik to Spacewalking: Soviet Space Firsts. History in the Headlines.” http://www.history.com/news/from-sputnik-to-spacewalking-7-soviet-space-firsts 2012.

[7] Steven J. Dick, “Why We Explore: The Birth of NASA.” http://www.nasa.gov/exploration/whyweexplore/Why_We-29.html 2008.

Soviet Union.[8] The second was the National Reconnaissance Office (NRO), established in 1961, which was committed to utilizing outer space for potential military uses.

## Project Mercury

One of the first goals of NASA was to launch a man into outer space as soon as possible. The first program was named Project Mercury, and seven astronauts were selected from the military's test pilot program. On May 5, 1961, Astronaut Alan Shepard was launched into a 15-minute suborbital space flight aboard Freedom 7. On February 20, 1962, John Glenn became the first American launched into Earth orbit, a feat accomplished by the Russians nearly a year before.[9]

## Project Apollo

The U.S. citizens' perception of Soviet superiority was the incentive needed for President John F. Kennedy to make a special request to Congress on May 25, 1961. He proposed that by the end of that decade, the U.S. government would commit to putting a man on the Moon and returning him safely. This speech was bold, challenging, and a strategic rhetorical move on the part of President Kennedy, and it was embraced with tremendous national and political will, as well as strong public enthusiasm. Thus, the social and political foundation was laid for a manned lunar landing, which led to the establishment of the ambitious Apollo program. Although the U.S. was behind in the

[8] Nick Skytland, "NASA Declassification Management Program: Corona Program." space.jpl.nasa.gov/programs/corona.html 2012.

[9] Brian Dunbar, "About Project Mercury." http://www.nasa.gov/mission_pages/mercury/missions/manned_flights.html 2015.

space race, Americans found themselves suddenly engaged in a dramatic competition in which they were determined to be the victor.

NASA’s budget was immediately increased by nearly 500 percent, and the Apollo program soon became the most expensive scientific endeavor undertaken by the United States. Expenditures in the 1960s were nearly $25.4 billion[10] (more than $200 billion in 2016 U.S. economic terms). Apollo employed more than 400,000 people from NASA and civilian contractors to complete the daunting goal on schedule.

From 1961 to 1964, NASA marched forward through the Mercury program, which consisted of a one-person space capsule. The Gemini program, which lasted from 1965 to 1967, was comprised of a two-man capsule.[11]

Meanwhile, the secret Soviet lunar landing program (declassified in 1990) was losing political momentum. There were internal tensions within the Russian government space organization due to administrative, technical, and financial difficulties. The Soviets attempted four launches for a Moon landing from 1969 to 1972, but failed each time.[12] In addition, the unexpected death of the chief space engineer, Sergey Korolyov, delayed the program even further, which led eventually to the cancellation of the Soviet lunar program.

October 1968 saw the launch of Apollo 7—the commencement of the ambitious U.S. schedule to land a man on the Moon by the end of the decade. On July 16, 1969,

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[10] NASA History, “Project Apollo: A Retrospective Analysis.” http://www.nasa.gov/ApolloMoon/apollo.html 2014.

[11] David Hitt, NASA Educational Technology Services. “What Was the Gemini Program?” http://www.nasa.gov/audience/forstudents/k-4/stories/what-was-gemini-program-k4.html 2011.

[12] Leonard David, “New Secrets of Huge Soviet Moon Rocket Revealed,” *Space.com*, February 7, 2011. Available at: http://www.space.com/10764-soviet-moon-rocket-secrets-revealed.html.

Apollo launched from Kennedy Space Center in Cape Canaveral, Florida. The launch was the first attempt of a manned lunar landing. U.S. astronauts Neil Armstrong, Edwin “Buzz” Aldrin, and Michael Collins were aboard the spacecraft heading for the Moon. When Neil Armstrong set foot on the Moon for the first time in human history on July 20, 1969, he spoke these famous words, “One small step for man, one giant leap for mankind.” From the start, American citizens were captivated by the race to the Moon, and television caused interest in the phenomenon to spread worldwide with approximately 530 million viewers.[13] Astronauts became national and worldwide heroes, and U.S. patriotism surged. Adults and children alike were inspired.

Ultimately, the NASA landing of a man on the Moon meant the United States was the “winner” in the space race against the Soviet Union, and the U.S. government’s passion for further human space exploration soon began to wane. In 1975, a joint U.S. and Soviet space mission, named Apollo-Soyuz, sent three American astronauts and two Soviet cosmonauts into space. The U.S. spacecraft docked successfully with the Soviet spacecraft, and the commanders of each mission greeted the other with an official handshake in space.[14] This joint mission became one of several symbolic events that signified the approaching end of the Cold War, as U.S. and Soviet political relations began to improve—although it can be argued that the Cold War did not officially end until the USSR collapsed some five years later.

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[13] Brian Dunbar, “Apollo 11 Mission Overview, The Eagle Has Landed.” http://www.nasa.gov/mission_pages/apollo/missions/spollo11.html 2015.

[14] Edward C. Ezell, “The Partnership: A History of the Apollo-Soyuz Test Project.” http://www.hq.nasa.gov/office/pao/history/SP-4209/toc.htm; 1978.

As the so-called Space Race (i.e., the competition between the U.S. and the Soviet Union regarding achievements in the field of space exploration) fizzled, U.S. interest in space exploration continued but at a much slower pace. The public became bored with five repetitious missions to the Moon, and NASA was losing momentum. NASA needed a new goal, and then-President Richard Nixon was not motivated to set another ambitious and costly plan like Apollo. Nixon viewed NASA as another domestic agency competing for taxpayer dollars, and no longer a “favored” program. The lasting impact of Nixon’s space doctrine was to terminate human space exploration which thereafter locked humans into low Earth orbit.[15]

## Space Shuttle Program

In 1972, after much thought and counsel, President Nixon decided to cancel the three remaining lunar missions, Apollo 18, 19, and 20. Instead, he favored shifting NASA’s decreased budget to a new and sustainable program: the creation of a partially reusable spacecraft named the Space Shuttle (formally termed the Space Transportation System (STS) program). The Space Shuttle was capable of reaching LEO, and it flew 135 missions between 1981 and 2011.[16] Two shuttles, Challenger and Columbia, were lost and 14 astronauts perished. However, during this 20-year period, STS launched several satellites, Skylab, the Hubble Space Telescope, and components of the International Space Station.

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[15] John M. Logsdon, “Ten Presidents and NASA: Richard M. Nixon, 1969-1974.” http://www.nasa.gov/50th/50th_magazine/10presidents.html 2008.

[16] T. A. Heppenheimer, NASA History Office. “The Space Shuttle Decision, NASA’s Search for a Reusable Space Vehicle.” http://history.nasa.gov/SP-4221/sp4221.html 2004.

## Space Stations

In 1973, NASA launched the space station called Skylab, which was a science laboratory and solar observatory. Three manned missions transporting three astronauts were conducted on Skylab, and records were set for human time spent in orbit. Skylab was sent into Earth's atmosphere in 1979 and disintegrated.[17]

After Skylab, NASA created several space laboratories, including Spacelab[18] and Shuttle-Mir, a cooperative space venture with Russia. Then the Space Station Freedom was launched and eventually became a component of the International Space Station.

Also of note, European heads of state met in Belgium in 1971 with hopes of contributing and participating in an international partnership with NASA's Space Shuttle program. This goal was realized in 1983 through Spacelab, an orbiting reusable laboratory in space housed in the cargo bay of the Space Shuttle. In the Spacelab, research and scientific experiments were conducted in several fields, i.e., microgravity, human performance in space, astronomy, life sciences, and orbital sciences. The Space Shuttle facilitated and set a new precedent for international relationships in a multidisciplinary setting. Altogether, 22 Spacelab missions were flown aboard the Space Shuttle from 1983 to 1998.

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[17] Dennis Armstrong, NASA-Part 1. "The History of Skylab." http://www.nasa.gov/missions/shuttle/f_skylab1.html 2003.

[18] Jessica Egan. NASA, "Spacelab Paved Critical Path to Space Station." http://www.nasa.gov/mission_pages/station/research/news/spacelab/#.VWild1I8KnM 2013.

## International Space Station

President Ronald Reagan was in office from 1981 to 1989, and was a strong supporter of NASA. Reagan overrode his presidential advisors and gave his strong support and approval for the creation of a space station, an inhabitable satellite that would ultimately become the International Space Station (ISS). In addition, Reagan invited U.S. allies to participate in the program, which would become a defining feature of the ISS.[19] Reagan set a new precedent for international cooperation in space, and as of March 2016, the ISS has joined with five space agencies, 25 different nations, and been visited by 224 astronauts from 18 different countries.

## Constellation Program

Following the Columbia space shuttle disaster in 2003, President George W. Bush sought to regain public trust and enthusiasm for manned spaceflight. NASA administrator Michael D. Griffin created a human space exploration roadmap known as the "Exploration Systems Architecture Study," which was formalized into law by the NASA Authorization Act of 2005 and named the Constellation Program.[20] Constellation was NASA's plan to return humans to exploring in space beyond low Earth orbit. The program began with the idea of exploring Mars and identifying what would be needed to accomplish this goal safely and effectively. The program called for three design reference missions: (1) the Orion crew capsule would dock with the ISS, stay in orbit for 180 days

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[19] President Ronald Reagan, "President Reagan's Statement on the International Space Station." State of the Union Address, January 25, 1984. See: http://history.nasa.gov/reagan84.htm.

[20] John F. Connolly, "Constellation Program Overview," NASA Constellation Program Office, 2006. http://www.nasa.gov/pdf/163092main_constellation_program_overview.pdf

or more, and then return the crew back to Earth; (2) the mission called for lunar sorties, or short seven-day missions to the Moon; and (3) the mission would have crews staying on the Moon for six months at a time and establishing a lunar outpost. In past generations, going to the Moon was the extent of U.S. exploration, but the Constellation included even more: a journey to Mars.[21]

## Current United States Space Policy

When President Barack Obama took office in 2009, he called for a review of current U.S. space policy. This report was known as the Augustine Commission, and its goal was to ensure that NASA was on an aggressive, yet sustainable path of ambitious space exploration.[22] The Augustine Commission believed the Constellation Program was extremely behind schedule and under-funded.[23] The Commission proposed three different options for human space exploration, but President Obama did not choose any of these. Instead, he cancelled the Constellation program in 2010 and rejected any plans for a return to the Moon.

Congress elected to retain components of Constellation as part of NASA's new plan. This included Orion (a deep-space, manned exploration vehicle), and the Ares V program (a heavy lift rocket, renamed the Space Launch System (SLS) by Congress in order to preclude its demise). Furthermore, both the lunar lander Altare and the Lunar

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[21] John F. Connolly, personal interview, NASA Johnson Space Center, November 4, 2014.

[22] Dennis Bonilla, "Review of U.S. Human Space Flight Plans Committee." http://www.nasa.gov/offices/hsf/home/index.html NASA 2009.

[23] Norman R. Augustine, Chairman, "Review of U.S. Human Space Flight Plans Committee: Seeking a Human Spaceflight Program Worthy of a Great Nation," October 2009. https://www.nasa.gov/pdf/396093main_HSF_Cmte_FinalReport.pdf.

Surface Systems (LSS) were cancelled. Instead, Obama proposed that NASA send astronauts to a near-Earth asteroid by 2025, and explore Mars by the mid-2030s. In addition, he extended funding for the ISS until 2024.[24]

Today the future of manned space exploration is being hotly debated among proponents and detractors of Obama's policies. For example, before President Obama made his speech at the Kennedy Space Center outlining the future of U.S. space policy, Elon Musk, founder and CEO of SpaceX, released a statement commending the President on his proposals:

> Cancellation [of the Constellation Program] was therefore simply a matter of time and thankfully we have a president with the political courage to do the right thing sooner rather than later. We can ill afford the expense of an "Apollo on steroids," as a former NASA Administrator referred to the Ares/Orion program. A lesser president might have waited until after the upcoming election cycle, not caring that billions more dollars would be wasted. It was disappointing to see how many in Congress did not possess this courage.[25]

Not unsurprisingly, the aerospace community is today frustrated by the lack of visionary leadership and political will, which in turn dampens the public's enthusiasm to reach further into our solar system. For example, John Connolly, NASA's Chief Exploration Scientist, described the Obama administration's philosophy by saying:

> NASA wondered what they would do with these parts and pieces they had been given. What in the world do we do with these random pieces that don't really fit together? There is no real vision. It's just pieces and parts. I am a "destination guy." And now I have no real drive or motivation to move forward. The lesson that I have learned is that no matter how much

[24] "President Obama on Space Exploration in the 21st Century," News Release, April 15, 2010. http://www.nasa.gov/news/media/trans/obama_ksc_trans.html 2010.

[25] Elon Musk, "At Long Last, an Inspiring Future for Space Exploration" *Spacex.com*, April 15, 2010. http://spacex.com/press.php?page=220100415 SpaceX 2010.

> money or energy we [at NASA] put into a project—the White House can shut it down.[26]

Similarly, Astronaut Neil Armstrong, commented: “When President Obama recently released his budget for NASA, he proposed a slight increase in total funding . . . . The accompanying decision to cancel the Constellation program, its Ares 1 and Ares V rockets, and the Orion spacecraft, is devastating.”[27] Likewise, Astronaut Gene Cernan, remarked on the current U.S. space policy in 2010:

> For the United States, the leading space-faring nation for nearly half a century, to be without carriage to low Earth orbit and with no human exploration capability to go beyond Earth orbit for an indeterminate time into the future, destines our nation to become one of second or even third rate stature. While the President’s plan envisages humans traveling away from Earth and perhaps toward Mars sometime in the future, the lack of developed rockets and spacecraft will assure that ability will not be available for many years.[28]

Robert Zubrin, President of The Mars Society, criticized Obama’s plan in an article in the 2010 New York Daily News:

> Under the Obama plan, NASA will spend $100 billion on human spaceflight over the next ten years in order to accomplish nothing. Obama called for sending a crew to a near-Earth asteroid by 2025. Had Obama not cancelled the Ares V, we could have used it to perform an asteroid mission by 2016. But the President, while calling for such a flight, actually terminated the programs that would make it possible. Without the skill and experience that actual spacecraft provides, the USA is far too likely to be on a long downhill slide to mediocrity.[29]

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[26] John F. Connolly, personal interview, NASA Johnson Space Center, November 4, 2014.

[27] Daniel Russ, “Neil Armstrong writes a letter to Obama, one that perhaps we should all read,” *Civilian Military Intelligence Group*, April 14, 2010. http://civilianmilitaryintelligencegroup.com/3778/neil-armstrong-writes-a-letter-to-obama-one-that-perhaps-we-should-all-read 2010.

[28] Frank Wolf, “Don’t Forsake U.S. Leadership in Space,” *Space News*, April 28, 2010. http://spacenews.com/commentaries/100425-dont-forsake-leadership-space.html 2010.

[29] Robert Zubrin, “Obama’s Failure to Launch,” April 19, 2010. http://marssociety.org/portal/obamas-failure-to-launch/.

With the cancellation of the Constellation program, the Space Shuttle, and the ISS in 2024, NASA's morale today is at an all-time low. Taken together, it is apparent that aerospace insiders who value human space exploration are extremely frustrated because they do not see that value mirrored in current U.S. space policy.[30]

[30] David Jackson, "Obama's NASA policy. The White House vs. Neil Armstrong," *USA Today*, April 14, 2010. http://content.usatoday.com/communities/theoval/post/2010/04/obama-to-talk-policy-after-criticism-by-neil-armstrong/1#.T

## Chapter V

## Research Methods

For my research I made use of numerous resources, including historical documents,  relevant periodicals and books, and personal interviews. I analyzed my data and categorized the resulting information into six evaluative categories: physiological, psychological, technological, economical, international, and national. By comparing the relative advantages and disadvantages of these categories vis-à-vis a Moon or Mars mission, I expected to derive a next logical step for NASA's human exploration program.

### Description of Sources

My research involved five stages. In the first stage, I reviewed relevant sources of information. The literature review and data collection involved acquiring relevant periodicals and books that contained comparative analyses, case studies, and/or policy studies on space exploration.

In the second stage, I conducted personal interviews with numerous aerospace industry insiders and government officials. These highly qualified participants were solicited from my professional network, grown over the last two years. All interview participants are among the foremost knowledgeable insiders in the industry. Criteria for choosing relevant aerospace insiders and government officials included: (a) the participant must have had 20+ years of experience in the space industry; (b) participants are or were employed as top-level decision makers, with strong spheres of influence in the space industry; (c) participants have worked on a space exploration project personally, in either a technical, medical, academic, or political capacity. I asked interview participants to compare the advantages and disadvantages of either a Moon or Mars mission across the six evaluative categories referred to above.

In the third stage, I aggregated and read sources of information in order to analyze the relative advantages and disadvantages of the Moon or Mars mission as the information related the six evaluative categories. This mapping process illuminated gaps or weaknesses that needed to be assessed in more detail. Identifying these gaps enabled me to engage in a direct search through more literature. Likewise, I also returned to interview participants, hoping to fill those gaps or weaknesses in the analysis. I went back to crosscheck with periodicals and more insider interviews, and questioned them further in order to derive a more thorough analysis across the evaluative categories.

In stage four, I assessed the compiled, comprehensive information and identified the relative advantages and disadvantages. The six categories were judged holistically, but each category was not necessarily of equal importance. I anticipated that the full analysis of all the categories would reveal that a mission to the Moon is more advantageous, and that it should become the next strategic direction of the NASA organization.

In the fifth stage, on January 11, 2016, I began an internship at NASA Headquarters in Washington, D.C. This is where policy decisions are made and then carried out throughout the nine NASA field centers around the United States. Working in this rich environment gave me even more insight to the strategy, operations, culture, and morale of NASA. In addition, it gave me immediate access to ask many research questions and conduct more interviews.

Interview Participants

As stated above, I chose knowledgeable participants who have been in the space industry for more than 20 years. Because this is a futuristic and strategic plan, there is limited written information. Therefore, I relied heavily on content gathered from these experts to formulate the next logical step for NASA and its pursuit of human space exploration. I provide below a brief description of each of the participants.

*John Connolly*: Mr. Connolly is the Chief Exploration Scientist for NASA, and he is employed at Johnson Space Center in Houston, Texas. He designs space exploration missions and finds safe ways for people to travel beyond Earth's orbit. He was heavily involved in the Constellation Program. He was a part of the robotic designs of the current Mars missions, the Curiosity and Opportunity rovers. In 2003, Connolly was a member of the Columbia Accident Investigation Board. He has appeared on television worldwide to explain NASA's Mars Missions. Connolly is currently on a NASA Intergovernmental Personnel Assignment as the Director of Space Studies at International Space University.

*Giovanni Fazio*: Dr. Fazio is the Senior Physicist at the Harvard Smithsonian for Astrophysics, Lecturer for the Harvard University Astronomy Department, and on the Academic Counsel for International Space University. He was the Principal Investigator for the first infrared telescope to fly on the Space Shuttle and the Spitzer Space Telescope, one of NASA's Great Observatories. Fazio is the author of more than 300 publications and has received six NASA Group Achievement Awards, the NASA Public Service Medal, and the Royal Society of London COSPAR Gold Medal.[31]

*Jeffrey Hoffman*: Dr. Hoffman is a five-time Space Shuttle astronaut, having logged more than 1,200 hours in space and traveled 21.5 million miles. On his first mission, he assisted in the successful repair of the Hubble Space Telescope. Hoffman received his Ph.D. in Astrophysics from Harvard University. In 2003, he was sent by NASA to Massachusetts Institute of Technology where he is today a professor in the Department of Aeronautics and Astronautics. Hoffman was awarded two NASA Exceptional Service Medals, and as part of the Hubble Telescope Rescue Team he was awarded the National Association Collier Trophy for Aeronautics and Astronautics.[32]

*David Kendall*: Dr. Kendall is the Senior Executive Advisor to the President of the Canadian Space Agency (CSA) and previous Director General of the Space Science and Technology of the CSA. He was also Vice President of the International Aeronautical Federation and is the author of over 180 publications. Dr. Kendall is currently the Chairman of the United Nations Committee on the Peaceful Uses of Outer Space.[33]

*Kathy Laurini*: Ms. Laurini is a 30-year veteran of NASA's Human Exploration Program, was a flight controller for the Space Shuttle, and a designer of the International Space Station. She currently heads NASA's office in the Netherlands and is the co-chair of the International Space Exploration Coordination Group (ISECG).

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[31] Giovanni Fazio, short vita, Harvard University. https://www.cfa.harvard.edu/~gfazio/bio.html.

[32] Jeffrey Hoffman, biographical data, NASA. http://www.jsc.nasa.gov/Bios/htmlbios/ hoffman.html.

[33] David Kendall, biography, International Aeronautical Federation. http://www.iafastro.org/ biography/david-kendall/.

*John Logsdon*: Dr. Logsdon is Professor Emeritus of Political Science and International Affairs at George Washington University (GWU), where he was an active faculty member for 38 years. Logsdon was the founder and director of the GWU Space Policy Institute and director of the GWU Center for International Science and Technology Policy. During the 2007–2008 academic year, he was a Distinguished Visiting Professor at MIT's Science, Technology, and Society Program. Logsdon was a member of the NASA Advisory Council and a member of the Council's Exploration Committee. He is a member of the Academic Council of the International Space University. In 2003, he served on the Columbia Accident Investigation Board and is the recipient of the Distinguished Public Service Medal from NASA. In 2005, Logsdon received the John F. Kennedy Astronautics Award from the American Aeronautical society. He is frequently cited as an authority on space policy by the *New York Times* and *Washington Post*, as well as many radio and television programs.[34]

*Gary Martin*: Mr. Martin is Director of the New Ventures and Communications Directorate at NASA Ames Research Center near San Jose, California. He oversees new business opportunities for NASA, including entrepreneurial partnerships, education, strategic communications, and he facilitates the development of NASA Ames' long-term strategy. He has been with NASA for more than 20 years, working primarily in the science mission and human spaceflight areas. He was named NASA's first Space Architect leading Strategic Planning for U.S. Space Exploration. Martin is a recipient of

[34] John M. Logsdon, Biography, Space Policy Institute, George Washington University. https://www.gwu.edu/~spi/faculty.cfm

NASA's Outstanding Leadership Medal and is on a NASA Intergovernmental Personnel Assignment at International Space University.[35]

*Scott Pace*: Dr. Pace is the Director of the Space Policy Institute at George Washington University's Elliot School of International Affairs. From 2005–2008, he served as Associate Administrator for Program Analysis at NASA. Prior to NASA, Pace was Assistant Director for Space and Aeronautics at the White House. He was Director of Space Commerce, and received the NASA Outstanding Leadership Award in 2008. Pace received a double Master's Degree at MIT in Aeronautics and Astronautics and in Technology and Policy, and a Doctorate in Policy Analysis from the Rand Graduate School.[36]

*Walter Peeters*: Dr. Peeters has been President of International Space University since 2011. He is the author of many articles on the commercialization of space, and has been a consultant with Virgin Galactic and many other organizations. He joined the European Space Agency in 1983, and in 1990 became the Head of the Office of the European Astronaut Center.[37]

*Joseph Pelton*: Dr. Pelton is an award-winning author of more than 35 books and has published over 300 articles in the field of space systems. His book, *Global Talk*, was nominated for a Pulitzer Prize. He is Director Emeritus of the Space and Advanced Communications Research Institute at George Washington University. Pelton served as Chairman of the Board, Vice President of Academic Programs, and Dean of the

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[35] Gary Martin, biographical information, Space.Com Expo. http://www.spacecomexpo.com/Content/Gary-L-Martin.

[36] Scott Pace, Elliot School of International Affairs, George Washington University. https://elliott.gwu.edu/pace.

[37] Walter Peeters, biography, International Space University. http://www.isunet.edu/prof-walter-peeters

International Space University. He has also held a number of executive positions at the SOMSAT Corporation and at INTELSAT where he headed strategic planning.[38]

*Harrison Schmidt*: Dr. Schmidt was a NASA astronaut on Apollo 17, a lunar module pilot, and a lunar geologist. He holds a Ph.D. in Geology from Harvard University. He was the next-to-last person to walk on the Moon's surface. Schmidt served as a U.S. Senator from New Mexico and was Chair of the NASA Advisory Council. In 2006, he wrote a book entitled, *Return to the Moon: Exploration, Enterprise, and Energy in the Human Settlement of Space*. He is currently the Director at Orbital ATK.[39]

*Robert Thirsk*: Dr. Thirsk is a Canadian astronaut who flew aboard the Space Shuttle Mission STS-78 and Soyuz-15 manned spaceflights to the International Space Station. Thirsk holds the Canadian record for the longest space flight (187 days) and the most time spent in space (204 days). He is the recipient of the NASA Distinguished Public Service Medal and is currently Chancellor of the University of Calgary.[40]

*Ray Williamson*: Dr. Williamson is the Senior Advisor and former Executive Director of Secure World Foundation. He was formerly the Research Professor of Space Policy and International Affairs at George Washington University Space Policy Institute and is a faculty member of International Space University. Williamson was a Senior Analyst and Senior Associate in the Office of Technology Assessment of the U.S.

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[38] Joseph Pelton, biography, Arthur C. Clarke Foundation. http://www.clarkefoundation.org/ about-us/leadership/dr-joseph-n-pelton-vice-chairman/.

[39] Harrison Schmidt, biographical data, NASA. http://www.jsc.nasa.gov/Bios/htmlbios/schmitt-hh.html.

[40] Robert Thirsk, biography, Canadian Space Agency. http://www.asc-csa.gc.ca/eng/astronauts/ biothirsk.asp.

Congress for more than 15 years. He is the author of more than 100 articles on space. Today he serves on Commission Five of the International Academy of Astronautics.[41]

[41] Ray Williamson, faculty biography, University of Cape Town. http://www.spacelab.uct.ac.za/ray-williamson.

# Chapter VI

## Research Limitations

My research was limited by what I can feasibly know about the scientific, technological, and engineering aspects of the missions, given my lack of expertise in those fields. Therefore, I supplemented my lack of knowledge in these areas by reading literature and periodicals. In addition, I interviewed multiple aerospace insiders and government officials who were able to explain and enlighten me on issues surrounding the scientific, technical, and engineering aspects of these missions.

## Chapter VII

## Moon and Mars: A Comparison

A journey to the Moon is approximately three days away, a distance of 239,000 miles, and humans can “come and go” because of its relatively close distance to Earth. The Moon has one-sixth of Earth’s gravity, which is generally considered not ideal for sustaining the bones and muscles of the human body. The Moon has no atmosphere or weather, and does not offer any protection from cosmic radiation. The amount of time the Moon takes to complete a turn on its axis is almost 28 days. Each day-and-night cycle is about 14 Earth days, meaning there are 14 days of steady daylight followed by 14 days of extreme darkness.

Moon explorers would encounter extremely high temperatures during the Moon “day” (approximately 250° F) and very frigid temperatures (approximately -380° F) during a Moon “night.” In addition, razor-sharp Moon dust, called regolith, is a serious hazard for astronauts and their equipment. The Moon seems to promise large amounts of natural ice in its frozen polar regions. This frozen water may be life-giving to humans, and a natural resource for rocket fuel if the water were split into its hydrogen and oxygen components. Because the Moon is only three days away, if something were to go wrong with the crew, equipment, or spacecraft, a rescue and return is feasible.

Mars, on the other hand, is at least eight months away, at a distance of approximately 46 million miles—and only when the Earth and Mars have an aligned orbit. Once a crew arrives at Mars, they would need to be prepared to stay for at least a year until Earth and Mars are again lined up orbitally. Therefore, there is no chance of a quick rescue and return operation from Earth if the crew on Mars were to encounter a problem.

Mars has about 38% of the gravity of Earth, which is better physiologically for human beings. It has an atmosphere of carbon dioxide and a more Earth-like day-and-night cycle. A Mars day is 24 hours and 39 minutes long. High temperatures can reach around 80°F in the daytime and can drop as low as -200°F at the poles. Mars does have some sort of water-ice, which might be a source of rocket fuel. There is a possibility that the Mars soil could be modified in order to grow food.

Upon first assessment, it appears Mars is a more people-friendly planet and a desirable location for humans. But the obstacle of distance is the "deal killer." This challenge alone generates problems of psychological stress, bone and muscle loss, and cancer-causing galactic radiation. Furthermore, the cumulative amount and weight of food, water, fuel, and medicine needed to complete a successful mission seems prohibitive. This also does not include the entry, descent, and landing (EDL) system, which must be capable of delivering at least ten times the mass and volume of our current robotic mission to Mars.[42]

[42] Anuradha K. Herath, "Why is it So Hard to Travel to Mars?" *Astrobiology Magazine*, April 18, 2011. See also: Walter Engelund, NASA Langley Research Center. http://m.space.com/11417-mars-mission-space-travel-challenges.html.

# Chapter VIII

# Consideration of the Critical Question from a Physiological and Psychological Perspective

Over the past 40 years, NASA has successfully landed a series of robots on Mars, beginning with Viking 1 in 1976. Most recently, the landing of Curiosity at Gale Crater, the seventh robotic landing on Mars, has inspired the American people and captured their attention.

In May 2012, NASA put together a study group that rendered a tentative goal of a human mission to Mars by 2033. There is a hefty price tag that goes along with this goal, as well a vexing set of challenges. In addition to technical and political obstacles, and unlike the earlier seven robots, humans traveling to Mars will need food, water, protective shelter, medical supplies, entertainment, friendship, and yes, a return ticket back to Earth. This chapter covers the unique set of problems that must be solved for a successful manned trip to and from Mars.

## Psychological Effects

Separation, long-term isolation, and the dynamics of living with fellow astronauts for an extended period of time are some of the challenges that must be addressed. While the Apollo missions lasted a week, the crews could still capture views of Earth, and they knew they were only three days away. Although Space Station astronauts rotate up to and home from the ISS about every six months, they can look out ISS windows, see their familiar home planet, and know they are a seeming “stone’s throw” from an expected safe return. This is not so with a trip to Mars. Every 26 months there is a brief optimal departure period from Earth, and the round trip would be expected to last two to three years. As the mission moves toward Mars, Earth becomes a small dot, and eventually fades into the vast universe of billions of twinkling stars.

Astronauts are not going to Mars to plant a flag on the surface like they did with Apollo. They are going to stay for approximately 18 months. In preparation for the psychological effects that astronauts might encounter, a group of astronauts from Russia, the European Space Agency, and China participated in the “Mars 500 Experiment” from 2007 to 2011 in Moscow. The study simulated a 520-day round trip to Mars in which volunteers lived and worked in a mock mission environment. The experiment generated helpful data on the psychological and social effects of people placed in a long-term, cramped living situation. During the study, communication with the outside world had a realistic time delay of 25 minutes, and there was a limited supply of food and other consumables. Some of the crew members reported trouble sleeping and exercising, and would isolate themselves from each other in a type of hibernation. But there were no reports of conflicts, and any difficulty the crew encountered, they resolved together as a team. Overall, the crew members were friendly with each other, and cultural and language differences did not create any significant problems. However, the effects of cosmic radiation and weightlessness were not able to be factored into this experiment.

## Physiological Effects

Even though space agencies have been launching astronauts into space for over 50 years, we still do not understand all of the adverse effects that space travel has on the human body. A few of these challenges include exposure to radiation and weightlessness, which can lead to cancer, bone loss, muscle atrophy, vision impairment, and possible brain damage.

NASA is currently conducting a study on astronauts Scott Kelly and his twin brother Mark. The twins agreed to a year-long study (actually 340 days) assessing the impact of long-duration space travel and the human body's reaction to exposure to weightlessness and radiation. Scott Kelly just returned from space on March 1, 2016, and the testing will still continue on both him and his brother Mark, who remained on land. The loss of muscle and bone, vision problems, as well as motion and balance will be tested and compared between the twins. The study will help NASA prepare to take humans farther into deep space.[43]

But there are major differences when undertaking a trip to Mars because a long-duration mission into deep space involves exposure to a different type of radiation. Scott Kelly was in LEO during his mission, and Earth's magnetic field protected the astronauts from the more severe radiation exposure that crews would encounter on a trip into deep space. An astronaut on the ISS encounters about 20 times the amount of radiation compared to Earth. But a journey to the Red Planet increases radiation 300 times the normal exposure for a human being.[44]

[43] Brian Dunbar, "Twins Study," NASA, January 19, 2016. http://www.Nasa.gov./twins-study.

[44] Alan Yuhas, "Marathon space flight just the start for Scott Kelly, Walking science experiment," *Guardian*, March 5, 2016.

Beyond LEO, humans will encounter galactic cosmic rays and solar particle events. NASA scientists do not have sufficient knowledge about radiation in space, and they are hesitant to predict the effects on a crew as it hits the spacecraft and would eventually threaten the astronauts during their stay on Mars. According to Brett Drake, Deputy Chief Architect for NASA's Human Spaceflight Architecture Team, NASA could reduce exposure to normal background radiation in space by building shielding into the spacecraft and the Mars habitats. Drake thinks NASA needs an improved method of predicting life-threatening solar flares, which spew extremely high doses of radiation, so astronauts can retreat to special storm shelters when the need arises.[45]

A radiation assessment detector, which was carried along with Curiosity to Mars, was operational during the transit from Earth to Mars. It was determined that if humans had been involved in the journey, their risk of cancer would increase by five percent. Unfortunately, this is higher than NASA's limits for an astronaut. Radiation in deep space can be very damaging as it leave a number of medical issues in the human body over a lifetime. Long-term exposure can lead to cataracts, as reported by 36 former Apollo astronauts who were part of high-radiation missions. On Earth, cataract surgery is a relatively common procedure, but such surgery would be impossible to perform during a mission to Mars. Also, there is a common problem with vision impairment, as experienced on the ISS. Bob Thirsk, a Canadian astronaut who holds the Canadian record for the longest space flight (187 days) and the most time spent in space (204 days), lost a

[45] Brett Drake, "The Deferred Dreams of Mars," *MIT Technology Review*, 13.05.10 (November/December, 2012).

significant amount of visual acuity. This situation is not unusual among astronauts who have lengthy missions; unfortunately, the damage is permanent.[46]

Another problem encountered by ISS astronauts is bone loss and muscle atrophy. On average, astronauts on the ISS lose about 1.7% of outer bone mass and 2.5% inner bone mass per month during lengthy stays. Even after a year of rehabilitation, they still may have significant bone loss.[47] Despite vigorous daily exercise while in space, muscle atrophy sets in. When these healthy astronauts return to Earth, they can hardly stand or walk and must be undergo rehabilitation.

If only a few of these psychological and physiological issues occur, the crew of a Mars mission will be weakened upon entry, descent and landing to the Mars surface. Imagine how difficult it would be for the crew to execute their mission there. These are just a few of the psychological and physiological challenges that must be solved before missions to Mars are undertaken. This is why "dress rehearsals" in cislunar space and on the surface of the Moon are critical for enabling a successful journey to Mars.

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[46] Erik Seedhouse, *Mars via the Moon: The Next Giant Leap* (Switzerland: Springer Praxis, 2016), 2-9.

[47] Seedhouse, *Mars via the Moon*, 2-9.

# Chapter IX

## Consideration of the Critical Question from a Technological Perspective

In this chapter I will discuss some of the technology both needed and planned by NASA to explore destinations in cislunar space, the Moon, and Mars. When NASA dictates a destination, it drives the development of key technologies and capabilities for U.S. space explorers. NASA focuses on these technologies because they ensure affordable and sustainable equipment that is needed to build NASA's ability to explore a variety of destinations. The architecture includes transportation systems, mission operations, habitation structures, and destination systems that will create an interrelated and evolving infrastructure that will guarantee a seamless transition from low Earth orbit, the Moon, and then to Mars.

With ambitious goals to go to Mars and beyond, the technological challenges are very real. The Moon could possibly be the best location for a technological proving ground. If we master the Moon, both in cislunar and on its surface, that will certify the technologies needed and become a logical staging area for future deep-space exploration. NASA will have opportunities to develop safe operations that will support decades of future missions while remaining in close proximity to Earth. This strategy will open up the pathways to Mars. The Moon is also an affordable and sustainable destination that can span itself over several U.S. presidential administrations.

NASA has identified a list of technologies that are essential to exploring beyond LEO and advance human presence in Earth's solar system. One of the technologies needed is a transportation system beyond low Earth orbit. Included in this are ground operations (facilities for launching spacecraft from Earth), the SLS heavy-launch vehicle, and the Orion crew capsule. Deep-space missions will need to develop high-efficiency in-space propulsion and power, protection from radiation, optical communication, and deep-space navigation and rendezvous.

Upon arrival, there must be EDL systems capable of delivering far greater mass than the present robotic missions. Surface power generators will be essential for energy and human space destinations. Astronauts will need long duration habitation modules that include life-support systems, radiation safety, protection from the climate, and medical assistance for crew health. Currently, the ISS is Earth-reliant and dependent on re-supply flights. Because longer missions could last one to two years, astronauts will need to be self-sufficient and Earth-independent. *In situ* resource utilization is a required development, as well as comfortable EVA spacesuits, and sustainable food and water systems. Also necessary are mobile exploration vehicles and eventually ascent propulsion to return back to Earth. Of course, this does not encompass all of the necessary technologies, but several of them will have to be created, matured and perfected over time.

Missions to the Moon will be useful in preparing for long journeys across Earth's solar system, and helpful in successfully demonstrating capabilities that are independent from Earth.[48] Returning to the Moon will be the cornerstone of deep-space human

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[48] NASA, "Pioneering Space: NASA's Next Steps on the Path to Mars," May 29, 2014. https://www.nasa.gov/sites/default/files/files/Pioneering-space-final-052914b.pdf.

exploration.[49] The creation and development of Orion and SLS are well under way, but there are still several gaps that need to be addressed as the necessary technologies are developed, modified, and integrated into NASA's exploration goals.

On February 3, 2016, the House Committee on Science, Space, and Technology's Subcommittee on Space held a hearing entitled, "Charting a Course: Expert Perspectives on NASA's Human Space Exploration Proposals." Several expert witnesses were present and testified. They included Paul Spudis, Senior Scientist of the Lunar Planetary Institute; Tom Young, former director of NASA's Goddard Space Flight Center; and John C. Sommerer, former Chief Technology Officer at John Hopkins University Applied Physics Laboratory and currently Chair of the Technical Panel for the "Pathways to Explorations Report," which is part of the National Academy of Sciences (NAS). The NAS conducts studies for the federal government and is comprised of experienced experts in all areas of space technology and members who were involved in the U.S. space program dating back to the early years of Mercury, Gemini, and Apollo. This non-profit, government-mandated committee is helping NASA determine its technology roadmap.[50] In his report, Sommerer stated that the technological demands of a crewed Mars mission are very challenging, and that there is a huge gap in current capabilities and funding.

The "Pathways to Explorations Report" lists 15 high-priority technologies that are necessary in order to go to Mars:

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[49] *NASA News*, "Voyages: Charting the Course for Sustainable Human Space Exploration," June 7, 2012. https://www.nasa.gov/exploration/whyweexplore/voyages-report.html#.VxQKAHrUfUc.

[50] National Academy of Sciences. http://www.nasonline.org/?referrer=https://www.google.com/.

One can summarize the situation by considering a matrix of the fifteen capabilities indexed by the four different types of challenges, resulting in sixty assessments. Eighteen of those intersections are rated green, meaning that progress can be expected with minimal risk. Twenty-four intersections are rated yellow, indicating significantly higher risk. eighteen of the intersections are rated red, indicating such hurdles as ‘no technical solution known’ and that no such systems have ever been developed. Having spent my life as a technologist, I can say that a large job is not altogether a bad thing. But it does require a great deal of discipline, and certain ruthlessness in pruning technologies that are not making needed progress. I applaud the fact that, with this Committee’s and the Appropriators’ help, NASA finally has a Space Technology Mission Directorate, which has recently made some significant contributions to the capabilities that my Panel identifies as high priority. One of those areas, essential to landing human on Mars, is entry, descent and landing. The technology developed for the NASA Curiosity robotic rover currently exploring Mars will not scale to the capabilities needed to land astronauts.

One of the jobs of the Committee is to establish a pathway for human exploration in to deep space. Understandably, the committee suggested that there are only a few set of destinations for humans in the solar system, given our knowledge coupled with human physiology. They suggested a plan and advocated that the U.S. needs to quit changing its mind. At a minimum, we should agree on a pathway that is satisfying to the public, even if it does not lead to Mars in the foreseeable future. A pathway that includes the surface of the Moon is one obvious possibility.[51]

[51] John Sommerer, Hearing of the House Committee on Science, Space, and Technology Subcommittee on Space, “Charting a Course: Expert Perspectives on NASA’s Human Exploration Proposals.” February 3, 2016. http://www.nationalacademies.org/OCGA/114Session2/testimonies/OCGA_170500.

## Chapter X

## Consideration of the Critical Question from an Economic Perspective

An analysis of contemporary reports and my interviews indicate that there is a significant economic advantage to a Moon mission versus a Mars mission. First, the estimated budget of a round trip to the Moon is substantially less than a trip to Mars. Second, a mission to the Moon is more in line with the current budgetary abilities of the U.S. government. Also, the Moon potentially has rich raw resources that might counter-balance the expense by bringing those resources to Earth.

When researching economic comparisons, I found little written information on the subject. I approached several experts and found that no one was willing to give me a written report of the cost analysis and comparison. One of the biggest challenges is the indefinite and unfounded estimates projected for a round-trip journey to Mars. In my research, I found reports as low as $80 billion and upwards of $1.5 trillion. These conflicting figures breed distrust and an unwillingness among Congressional leaders to commit U.S. taxpayers' dollars to such an ill-defined mission. At a House Committee hearing on Human Space Exploration on February 3, 2016, Mr. Tom Young, former Director of Goddard Space Flight Center stated:

> It is hard to sell a plan until you have a plan. That is kind of "step one" of the process, in my view. My other comment is that it is just not any plan; it must be a plan that people, both pro and con, can recognize as credible—and that the ingredients of the plan [truly] exist. I think there is a reasonable probability that in the next two decades we will spend $180 billion on human space exploration, which is not a bad down payment. In

> my view that needs to be a critical part of the plan, but I do think it will have to be augmented.[52]

Attending the same hearing was Rep. Ed Perlmutter (D-CO) who also voiced his concerns over the vague and confusing budget analyses of proposed missions: "So, Dr. Sommerer, you said that according to your research and the panel's investigation this was twenty to forty years and at least half a trillion dollars. How did you come up with that?" Sommerer replied, "I do not want to say that it is a half a trillion. It is on the order for half a trillion, but maybe we will get by with 180 billion."[53]

In addition, the public has an exaggerated perception of the amount of taxpayer money spent by NASA. The average American thinks that the NASA budget accounts for 2.5 percent of the entire federal budget. In truth, it is approximately 0.5 percent.[54] Whatever the costs may be, NASA needs to do a better job of communicating financial facts in order to rally public support for future human space missions. Sommerer continued to testify concerning limited budgets and the disoriented vision of the future of human space exploration:

> To be explicit and to set the scale of the problem, the Technical Panel, aided by independent cost estimation contractors, and using and innovative process that respected the importance of development risks based on technical challenges, capability gaps, regulatory challenges, and programmatic factors, and the need to retain a reasonable operational tempo, concluded that the first crewed Mars landing might be possibly 20-40 years from now, after a cumulative expenditure of on the order of half a

52 Tom Young, Hearing of the House Committee on Science, Space and Technology Subcommittee on Space, "Charting a Course: Expert Perspectives on NASA's Human Exploration Proposals," February 3, 2016.

53 Ed Perlmutter and John Sommerer, Hearing of the House Committee on Science, Space, and Technology Subcommittee on Space, "Charting a Course: Expert Perspectives on NASA's Human Exploration Proposals." February 3, 2016.

54 Mars Generation Survey. http://www.exploremars.org/wp-content/uploads/2013/03/Mars-Generation-Survey-full-report-March-7-2013.pdf.

> trillion dollars. The actual time frame and cost will depend greatly on the pathway chosen to achieve the goal of going to Mars and candidly, the fastest and least expensive pathway that we examined comes with enormous risks to both the success for the missions and lives of the astronauts conducting them.[55]

NASA's current plans have serious deficiencies with regard to the significance of intermediate destination, logical feed-forward, dead-end systems, and exceedingly high development risks. To quote the Technical Panel's final briefing to the entire NRC Committee in 2014: "In the current fiscal environment, there are no good pathways to Mars."[56]

The Aerospace Safety Advisory Panel (ASAP), founded by Congress in 1968, is a panel tasked with advising on safety protocols and giving recommendations to NASA leadership. This panel holds quarterly public meeting and conducts fact-finding operations while visiting NASA centers and identifying potentially dangerous and hazardous situations. In its 2015 annual report, the Panel expressed concern that NASA lacked detailed plans in the areas of technology, vehicle design, and the agency's budget,[57] and articulated some reservations about NASA's ability to carry out a successful manned mission to the Red Planet. The panel's primary reason? NASA's inability to provide adequate details in two areas: technology and budget.

When NASA's leadership was asked to comment on this report, they said it was too early to create a detailed report. They said they were reluctant to design spacecraft and technologies needed for a mission to Mars, citing that they expect technologies to

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[55] Sommerer, Hearing of the House Committee, February 3, 2016.

[56] Sommerer, Hearing of the House Committee, February 3, 2016.

[57] Aerospace Safety Advisory Panel, NASA. http://oiir.hq.nasa.gov/asap/

advance greatly in the next two decades. There was also deep concern about a decision by the next presidential administrations to eliminate what NASA may plan now. But the ASAP panel believes if a mission—any mission—is well designed, with supporting facts and figures, NASA will receive support from the next president.[58] At Kennedy Space Center in April 2010, President Obama reiterated his commitment to a manned Mars' mission:

> By 2025, we expect new spacecraft designed for long journeys to allow us to begin the first-ever crewed missions beyond the Moon into deep space. We'll start by sending astronauts to an asteroid for the first time in history. By the mid-2030s, I believe we can send humans to orbit Mars and return them safely to Earth. And a landing on Mars will follow. And I expect to be around to see it.[59]

Regrettably, since this announcement, NASA has been a casualty of budget cuts that will have long-lasting impacts on spacecraft designed for long-distance deep space missions. As these cuts find their way into Mars manned missions, that will determine when humans might navigate their way to this challenging destination. A manned mission to the Red Planet requires an enormous amount of research, development, and financial investment. The current U.S. space policy does not appear to have the political or fiscal will to commit to such an ambitious goal. Ayana Howard, Chair of the Robotics Doctoral Program at Georgia Institute of Technology states:

> Unfortunately, development is closely tied to budget . . . .  If sufficient funding is made available, then scientists and engineers should be able to develop and integrate the required EDL components necessary for a

[58] Rina Marie Doctor, "Safety Panel Doubts NASA's Capability for 2030 Manned Mars Mission." *Tech Times,* January 19, 2016.

[59] "President Barack Obama on Space Exploration in the 21st Century." Kennedy Space Center, April 15, 2010. http://www.nasa.gov/news/media/trans/obama_ksc_trans.html 2010.

> human Mars mission within the next thirty years. If not enough resources are allocated, this timeline might not be feasible.[60]

At a minimum, the U.S. spaceflight program budget needs to grow at the rate of inflation. Equally important, a plan needs to be developed that demonstrates a reasonable timeline that is immune from partisan politics. The sustainable path to deep-space, manned exploration depends on a strategy where stakeholders from government, industry, international partners, and the public are vested in the program's success. The power of partnership will maintain ambitious human exploration plans through its ups and downs as proven by the collaboration of many nations and private companies invested in the success of the ISS. A mission to the Moon, Mars, or beyond should not be any different. It is my belief that the United States and NASA should lead the charge "I would like to conclude with some of my own views. I understand that there is bipartisan support for a "go as we pay" approach to human spaceflight. But just as it is not feasible to take a cross-country trip on a child's allowance, because of threshold costs, we may well never be able to get to Mars at our current expenditure level. It might be better to stop talking about Mars if there is no appetite in Congress and the Administration for higher human spaceflight budgets; and more disciplined execution by NASA. At a minimum, we should agree on a pathway that is satisfying to the public, even if it does not lead to Mars in the foreseeable future. A pathway that includes the surface of the Moon is one obvious possibility."[61]

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[60] Anuradha K. Herath, "Why Is It So Hard To Travel to Mars?" *Space.com*, April 18, 2011. Walter Engelund, NASA Langley Research Center. http://m.space.com/11417-mars-mission-space-travel-challenges.html

[61] Sommerer, Hearing of the House Committee, February 3, 2016.

## Chapter XI

## Consideration of the Critical Question from an International Perspective

The outcome of our space-related accomplishments are not achievements of the United States alone. Our success in space has always been  part of an internationally shared endeavor—including the Apollo program. Former astronaut Harrison Schmidt made this observation:

> A lot of people don't know that there has always been international cooperation. NASA has always used other countries—as they did for the Gemini and Apollo programs. From a geopolitical perspective we have to cooperate in the future. We should offer opportunities for other nations to participate. But I think if you try to manage future missions internationally, it is doomed to failure. You have to have a designated leader.[62]

The ISS—a tribute to the shared cooperation and sacrifices of many countries—is a crowning triumph in the arena of worldwide collaboration. With over 80 countries involved, the ISS just celebrated 16 consecutive years in a low Earth orbit. Together, significant scientific breakthroughs have been achieved that have transformed how human beings live on Earth, as well as groundbreaking research on the effects of microgravity on the human body over long periods of time.

As the technological revolution accelerates, many countries are partnering to operate a variety of technologies, including global navigation systems. Space-faring nations are on the rise, and certain countries no longer hold a monopoly on technology in

[62] Harrison Schmidt, Apollo 17 astronaut, former New Mexico Senator, and one of the last men to step on the surface of the Moon. Personal interview, International Space University, July 17, 2015.

space. We must find a way to continue the pattern set by the ISS in order to guarantee that competition does not overshadow international cooperation. William Burns notes:

> The International Space Station remains a leading space platform for global research and development. The Station is the foundation for future human exploration to an asteroid, the Moon, and ultimately to Mars. It is a lasting testament to how much more we can accomplish together than we can on our own.[63]

One group focused on international cooperation to maintain openness and inclusiveness is the International Space Exploration Cooperation Group (ISECG), a consortium of 14 space agencies.[64] ISECG was created on the platform of a shared vision of coordinated human and robotic space exploration focused on solar system destinations where humans may one day live and work. ISECG is a voluntary, non-binding international coordination effort through which the individual agencies may exchange information regarding their interest, plans, and activities in space exploration. This international organization works together to focus on strengthening both individual exploration programs, as well as the collective effort.[65] One member, Kathy Laurini said,

> I work for ISECG and lead NASA's engagement in the ISECG, which is a non-binding group of space agencies that have common desire for human space exploration. I try to create the foundations and partnerships with NASA as a leader in space exploration. This keeps our international partners informed on what NASA is doing. The other space agencies bring a lot of good ideas to the table and they have a desire to be part of a bigger effort as we go forward. This consultation and consensus we do builds collaboration to help push forward our common goals.[66]

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[63] William J. Burns, Deputy Secretary of the U.S. International Space Exploration Forum, January 9, 2014. http://iipdigital.usembassy.gov/st/english/testtrans/2014/01/20140109290196.html#axzz3xK4Xkyae.

[64] The agencies .include: ASI (Italy), CNES (France), CNSA (China), CSIRO (Australia), DLR (Germany), ESA (Europe), ISRO (India), JAXA (Japan), KARI (South Korea), NASA (United States), SSAU (Ukraine), Roscosmos (Russia), and UKSA (United Kingdom).

[65] http://www.globalspaceexploration.org/about-isecg.

[66] Kathy Laurini, ISECG Co-Chair, Exploration Roadmap Working Group. Personal interview, International Space University, July 28, 2015.

“The Global Exploration Roadmap,” produced by ISECG in August 2013, is a well laid-out plan that conveys the platform and strategy for coordinating both robotic and human exploration throughout the solar system. It reflects international preparedness for cooperative space missions to the Moon, asteroids, Mars, and beyond. Space agencies worldwide agree that human space exploration will be more successful if it includes many nations because there are so many obstacles in the way of accomplishing these missions. In addition, they agree that by pursuing these goals, the benefit to people on Earth is quite extraordinary intellectually, culturally, socially and economically. ISECG meetings have generated innovative ideas, as well as thoughts for problem solving, and in turn have strengthened relationships among the member space agencies. These partnerships will be required for a sustainable human presence in space. Yang Liwei, China’s first astronaut, who flew the Shenzou mission in October 2003, stated: “I think the development of space endeavors is not for one nation or one country. I myself, as an astronaut, believe that the multinational, the international cooperation, is the future triumph of the development of space industry.”[67]

The Moon and Mars are interesting and important destinations in the human exploration effort. We need to build on the capabilities and expertise that we have today and evolve them incrementally to meet the challenges that face us. The best approach would be to go to the Moon first and then solidify partnerships that will help us get to Mars. The Moon is on the critical path to Mars, and we can go there with international partners if we can demonstrate the technical abilities together as a unified team. There

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[67] Quoted in: Clara Moskowitz, “Future space exploration hinges on international cooperation, astronauts say,” *Space.com* April 29, 2010. http://www.space.com/8297-future-space-exploration-hinges-international-cooperation-astronauts.html.

will be significant challenges and many problems to solve and NASA can't do it alone. Every space agency will need to contribute their capabilities.

In 2014, the National Research Council released their report on NASA's human spaceflight plans. The Council's report commented on the subject of cooperation with our international partners:

> International collaboration has become an integral part of the space policy of essentially all nations participating in space around the world. It is evident that U.S. near-term goals for human exploration are not aligned with the goals of the nation's traditional international partners which look toward human operations on the lunar surface.[68]

At present, our international partners do not want to go to Mars; they want to go to the Moon. However, President Obama's comment was: "We've been there, done that." There is a serious divergence between the current U.S. administration and its international space partners. While it is true that the U.S. has set foot on the Moon, other nations have not yet done so. I suspect the rationale for their decisions comes down to money and affordability. With most national space budgets under severe restraint through budget cuts, the next logical step (given the realities of the geopolitical landscape) strongly suggests a return to the Moon.

If we wish to advance the cause of global peace and prosperity, it is vital that we make shared space exploration an international priority. In doing so, we as a species will accelerate our progress here on Earth while we continue to strive to unlock the mysteries of our vast universe.

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[68] "Pathways to Exploration; Rationales and Approaches for a U.S. Program of Human Space Exploration 2014," National Academies Press. http://www.nap.edu/catalog/18801/pathways-to-exploration-rationales-and-approaches-for-a-us-program.

## Chapter XII

## Consideration of the Critical Question from a National (U.S.) Perspective

In order to maintain the United States' status as a world power, the U.S. must continue to be the leader in technology, science, and space. In spite of seemingly urgent priorities, daily pressures, and Earthly challenges that face the American people, we must remain committed to space exploration. Space inspires our children, fuels invention and innovation, and provides tangible benefits. It improves health, security, clean energy, technology, and our overall quality of life. It would be interesting to see what our life on Earth would be like had we not pursued a trip to the Moon in the 1960s.

From July 29, 1969 to December 11, 1972, astronauts walked, drove, researched, and even golfed on the surface of the Moon. But when President Nixon cancelled the Apollo program in 1972, any prospect of a return mission to the lunar surface became quite bleak. Now, more than 45 years after leaving that last footprint on the Moon, the U.S. space program find itself stagnant in LEO with no particular destination in sight. The lasting imprint of the Nixon space doctrine still haunts us today in 2016.[69]

President George W. Bush's Constellation Program promised astronauts a return to the Moon by 2020. But when President Obama was elected, this vision was terminated following the unveiling of his current U.S. space policy. NASA's human space exploration program remains a vague and aimless plan that provides little or no promise

[69] Logsdon, *After Apollo*.

of defined timelines and destinations. Meanwhile, other space-faring nations march boldly forward as NASA remains spinning in circles, chasing its tail.

On January 20, 2016, NASA officials admitted that the Space Launch System (SLS), the agency's next big rocket, is a vehicle without a mission plan, and the agency acknowledged what is essentially an "empty flight manifest"[70] for the SLS at NASA's Kennedy Space Center (KSC) during a meeting to discuss the uncertainties facing the SLS. The first scheduled test flight with humans aboard has already been delayed once, and the schedule for future SLS tests is tentative. There is no definitive launch schedule for the rocket after its first manned test flight now scheduled for September 30, 2018. After that, SLS's next flight dates are mostly tentative, and the rocket does not have any definite mission plans, only the promise of going to an asteroid and then to Mars—someday. During the KSC meeting, two NASA administrators blamed NASA's funding on the lack of SLS scheduling.[71]

Eventually, there will be a government that will send astronauts back to the Moon. Will it be China? Russia? The European Space Agency? A joint government-commercial enterprise? Maybe NASA will finally realize that this is the progressive, sustainable step to providing the rehearsal needed for successful ventures into deep space. What is truly necessary is bold vision and strong leadership from the White House to spur the United States toward adventurous and sustainable achievements in manned space exploration.

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[70] Loren Grush, "NASA officials admit space launch system is a rocket without a plan," *The Verge*, January 12, 2016. http://www.theverge.com/2016/1/12/1075811/nasa-ksc-meetings-sls-rocket-undertain-launch-dates.

[71] Grush, 2016.

There is continual talk among NASA officials about a journey to Mars, but there are no real timelines or a clear-cut program in place. Mars is definitely the goal on the horizon, but realistically the initial goal is to acquire the technology and knowledge necessary to live in deep space for long periods of time. The Moon represents a critical and progressive step to test our abilities, which will lead us to a successful trip to the Red Planet.

The good news is we don't need to develop much new technology to return to the lunar surface, nor do we need hundreds of billions of dollars. According to John Connolly, it would cost approximately $3 billion for a return trip to the Moon. In addition, only a few technologies would need to be developed for longer stays. NASA and its partners need to create life-support systems, learn to extract local available resources, and to provide living quarters that shield humans from radiation. As we test these capabilities, it is also an advantage that the Moon is a close return journey of only three days. David Kendall, Director General of the Canadian Space Agency, and chairman of the United Nations Office for Outer Space Affairs (UNOOSA), commented on NASA's return to the Moon in an interview:

> I think one could go to the Moon easily once the United States develops a large rocket. The technology is straightforward with not any real show-stopping problems. I think that if NASA at the highest levels was to invite partners to join a Moon mission there would be great interest. I even think China would be open to this. People need inspiration and I believe people still see that in space exploration. When will we go back to the Moon? I don't know. I think it will come. I am positive that we will not sit in LEO for the next thirty years. But, I do believe the next step will be the Moon. It is the most conservative step beyond LEO that makes sense. But it has to be sold right, and the United States doesn't have the leadership in place right now to make it happen.[72]

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[72] David Kendall, Chair of UNOOSA, Director General of the Canadian Space Agency. Personal interview, International Space University, July 23, 2015.

The Moon and Mars are both very interesting and important destinations in the human exploration effort. It is important that the U.S. builds on the capabilities and expertise it has today and then incrementally evolve them to meet the challenges that continue. The best approach would be to go to the Moon first while solidifying the partnerships that will help us get to Mars. The Moon is on the critical path to Mars, and we can go there with international partners if we can demonstrate the technical abilities together as a unified team. There will be substantial challenges and many problems to solve, and NASA cannot do it alone. But I do not believe NASA wants any other country to lead. Every space agency will need to contribute their capabilities to the missions.

Human spaceflight and space itself are still tremendous sources of pride for Americans. It is essential that our next president taps into that pride and maintains the United States' leadership in space. It is a meaningful part of our history, and the public is getting more excited about making this happen again. But it is going to require committed leadership in the White House, with genuine dedication and unwavering persistence coupled with follow-through. The next president will have to take into account the geopolitical and fiscal situations, set up a winning formula, and then passionately communicate this to the American people, which will in turn be passed along to the NASA organization.

Geopolitical competition always fuels rapid advances in technology; unfortunately, most of today's major technological advances have been triggered by threats of some sort. Ultimately, the threat of competition for dominance will drive the next space missions. When citizens do not feel safe, suddenly an availability of funds will appear. I am unsure when all of these conditions will intersect, but I am confident there will be motivation and common vision for an aggressive schedule of space flight missions.

The reality is that each step will not be comparable to Apollo. But with each step we will build consensus that human exploration is worth doing. Space is a strategic domain, and it is worth the sacrifice for the United States government to invest in space exploration. We inspire, we educate, we drive innovation, we create new knowledge, and better our life on Earth. Kathy Laurini felt that inspiration:

> I was nine years old during Apollo 11, and it influenced me to be an engineer. It stopped the world! I have given NASA tours to my friends, and then their children went on to become engineers. Space inspires the lives of people and we need to communicate everything we accomplish, because creating this awareness pays large dividends in adults, as well as our children.[73]

As we return to the Moon, NASA human exploration missions must be independent of the start-stop cycle of the U.S. government's political games. Over and over again, we have witnessed the start of a bold U.S. space program, only to find Republicans presidents canceling Democrat initiatives, and Democrat presidents canceling Republican initiatives. Unfortunately, this pattern gets nothing of significance accomplished. In February 2016, Rep. Brian Babin said:

> There are thousands of men and women in this country whose days are impacted by the decisions we make in this building. It is easy for people confined to the Beltway Bubble to forget that our pride as Americans comes from the hard work and determination to make this world better. The men and women of NASA working on our human exploration programs are not pawns to be moved around a chess board in the latest game of chicken that the Administration chooses to play with Congress. We must ensure NASA's work focuses on the will of the people, not the political whims of whatever President is in office at the time.

[73] Kathy Laurini, NASA. Space Shuttle Flight Controller, Designer of the International Space Station, Co-Chair of ISECG, and 30 year employee of NASA. Personal Interview, International Space University, July 23, 2015.

> NASA's human exploration program has been through a tumultuous seven years, with a new president to be chosen by the end of this year. We must ensure that there is a constancy of purpose in our planning and a surefooted roadmap in place for the future. Human exploration has a long and storied history of being non-partisan. It is not a Republican or Democrat issue. It is an American issue. We need to get the politics out of this important program.[74]

NASA should lead an international partnership similar to the plan that was executed with the ISS. If we sit back and engage in political competition, China will charge ahead. I am convinced that now is the time for the United States to courageously step up and take charge of a global partnership, with a renewed passion for human space exploration. If we do not, we might have to step back and follow someone else.

[74] Brian Babin (R-TX), Hearing of the House Committee on Science, Space and Technology Subcommittee on Space. "Charting a Course: Expert Perspectives on NASA's Human Exploration Proposals." February 3, 2016.

# Chapter XIII

## Findings and Recommendations for U.S. Space Policy

NASA's space policy is confused and disorderly, with many visionary goals but no defined and strategic plans for future manned missions. The journey to Mars is no more than a "pie in the sky" because NASA has no budgets or the technology to achieve these plans. I am not criticizing NASA. In fact, I am a life-long fan, and have been so since I was a young girl who watched Neil Armstrong and Buzz Aldrin step foot on the Moon in July 1969. I would like nothing more than for NASA to go to Mars, but what is necessary is a step-by-step logical schedule of short-term realistic goals. Each milestone must be interesting to the public, even while NASA incrementally builds its space-faring capabilities. This type of plan is sustainable and could be fiscally mapped for Congress. The U.S. must create a logical, cumulative, affordable plan that leads us to our ultimate destinations. Realizable, short-term space goals will build long-term and enduring space policy—and long-term credibility with U.S. taxpayers and Congress.

On March 15, 2016, Congressman, John Culberson (R-TX), Chairman of the Committee on Appropriations Subcommittee on Commerce, Justice, Science, and Related Agencies, stated his views on the FY2017 NASA budget:

> It is difficult for us to imagine that the White House would expect the Congress to cut NASA by over a billion dollars and has not given you the support that you need. NASA just accepted a new group of applications for astronauts with over 18,300 applications for 14 astronaut spots. That is an indication of the level of support the country has for the space program. Every time there is a major mission launch the NASA website becomes one of the busiest, and OMB [the White House] refuses to give you the

> support you deserve. This committee will make sure you get the budget you need. It will be a tough budget year but we will be behind you every step of the way. It is frustrating when we love NASA and want you to stay the course.[75]

U.S. space policy should contain several attributes in order to maintain a consistent tempo from administration to administration. The missions should demonstrate to taxpaying citizens, Congress, and industry that there is continual progression in human space exploration. This will produce confidence in NASA's long-term strategy and in the leaders of our country to perform what was promised. The next destination NASA chooses should be inspirational and reflect significant scientific, economic, and geopolitical advantages. The pathway forward should also reflect responsible progression, both fiscally and technologically.

On February 25, 2016, Culberson gave his assessment of the current situation at NASA:

> We need to make NASA less political, more professional, and give them the ability to see far into the future with knowledge and confidence that the Congress will be there behind them. Over the last twenty years NASA has spent more than twenty billion dollars on cancelled development programs. No company, no entity, no agency of the federal government can function in this environment.[76]

Also commenting at the same hearing was Eileen Collins, first female pilot and first female Commander of the Space Shuttle: "Program cancellations made by bureaucracies behind closed doors, without input by the people, are divisive, damaging,

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[75] House of Representatives Committee on Appropriations Subcommittee on Commerce, Justice, Science, and Related Agencies, Budget Hearing NASA FY 2017, March 15, 2016.

[76] Marcia S. Smith, "Witnesses Support Goal of NASA Restructuring Legislation, But Not Specifics." *Space Policy Online*, February 29, 2016.

cowardly, and many times more expensive in the long run. A continuity of purpose over many years and political administrations will avoid surprises that set us back years."[77]

[77] Eileen Collins, Hearing of the House, Science, Space and Technology Committee, February 25, 2016.

# Chapter XIV

# Conclusion

NASA's next logical step in exploring beyond low Earth orbit is manned missions to the Moon. It is a natural satellite and possibly a future research laboratory that is close, and relatively accessible. Its close proximity makes it a rational proving ground for future manned mission to Mars and beyond. Equipment, systems and hardware could be proven and tested to check their reliability in a radiation rich environment. The Moon's reduced gravity is similar enough to Mars to test human performance and yield the knowledge needed to make sure that our astronauts will be safe. Mars simulations could easily be performed in long duration visits realistically assessing adaptability of the crew, both physiologically and psychologically. Surface hardware including habitation structures, life support systems, power generators, mobile vehicles, and *in situ* resources could be developed and matured. Everything that is accomplished on the Moon should reflect a cumulative, layered, stair step process towards a successful crewed mission to Mars.

Canadian astronaut Chris Hadfield has flown three space missions and served as Commander of the ISS. He was inspired to become an astronaut when he watched the Apollo 11 Moon landing on television from a small farm in southern Ontario, Canada. Hadfield is anxious for people to venture out into deep space, but he believes the next logical step is returning to the Moon and building lunar colonies. "We will be on the International Space Station for another ten years or so, and where is the next obvious place we'll go? The Moon. It's only three days away. . . . The Moon is an ideal testing . . . . we need to be able to get everything right and not kill everybody."[78]

The European Space Agency has recently announced its plans to return to the Moon to create a "Moon Village." It intends to have a lunar colony in place by the end of the 2020s.[79]

When NASA went to the Moon from 1969 to 1972, it was for footprints and flags. The few astronauts who went spent very little time there, and that was nearly fifty years ago. The "New Moon" vision will be to stay for long periods of time and learn to actually live there. During these lengthy missions multitudes of technologies will be tested that will eventually be needed for life in deep space and travel throughout the solar system. As the clock ticks on the termination of the ISS, it is time to plan the return to the Moon. There is no doubt that this will be NASA's next logical leap beyond low Earth orbit. Wendell Mendell, Retired Chief Planetary Scientist and Assistant Administrator for NASA where he was employed for 50 years, says it well: "The lunar base is part of an overall plan that has legs, that makes sense. We're moving the human species out into the solar system."[80]

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[78] Matt Burgess, "Chris Hadfield: Moon colonization is obvious next step," *Wired.Co.UK*, January 22, 2016. http://www.wired.co.uk/news/archive/2016-01/22/chris-hadfield-Moon-mars-spacex.

[79] Jeff Foust, "FAA Advisory Group Endorses Moon Village Concept." *Space News*, December 15, 2015.

[80] Mendell, quoted in: Thomas D. Jones, "How We'll Live on the Moon," *Popular Mechanics*, September 2007.

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